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Issue 2

Contract NAS8-31854

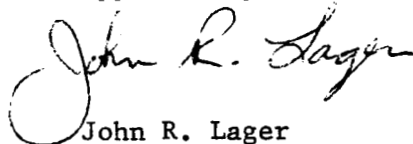
Design, Fabrication and Test of a
Lightweight Shell Structure

Phase III

Quarterly Progress Report No. 2

June 27, 1977 through September 25, 1977

Approved By:



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Prepared For:

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This quarterly progress report is submitted in accordance with the requirements of Exhibit "B", Report Requirements of the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Contract NAS8-31854.

Introduction

The scope of the contract is being changed at the request of NASA-MSFC due to a reduction in program funding. The proposed reduced scope of work involves building only the aft one-half section of the originally designed and analyzed shell structure. A complete set of drawings for this reduced size shell structure is included in this report. Shell fabrication is progressing smoothly with twelve (12) of the required twenty four (24) graphite/epoxy orthogrid panels completed and detail parts for the other twelve (12) completed.

Design

The aft one-half of the shell structure, from station 178.0 to station 257.0 as defined in figure II-14 of the contract Phase II Interim Report, will be fabricated. The joints at station 178.0 have been modified to provide external fixture attachment and the three Orbiter/Space Vehicle attachment and load reaction assemblies have been omitted. An isometric view of the development shell structure is shown in figure 1. The complete shell structure to be fabricated is defined in design drawings NAS8-318450, -318451, -318452, -318453, -318454 and -318455 included in this report. The only change anticipated in this design is making the aluminum lug defined in Detail D of drawing NAS8-318450 in three separate pieces rather than the as shown integrally machined part which results in a significant reduction in manufacturing cost without sacrificing structural integrity of the joint.

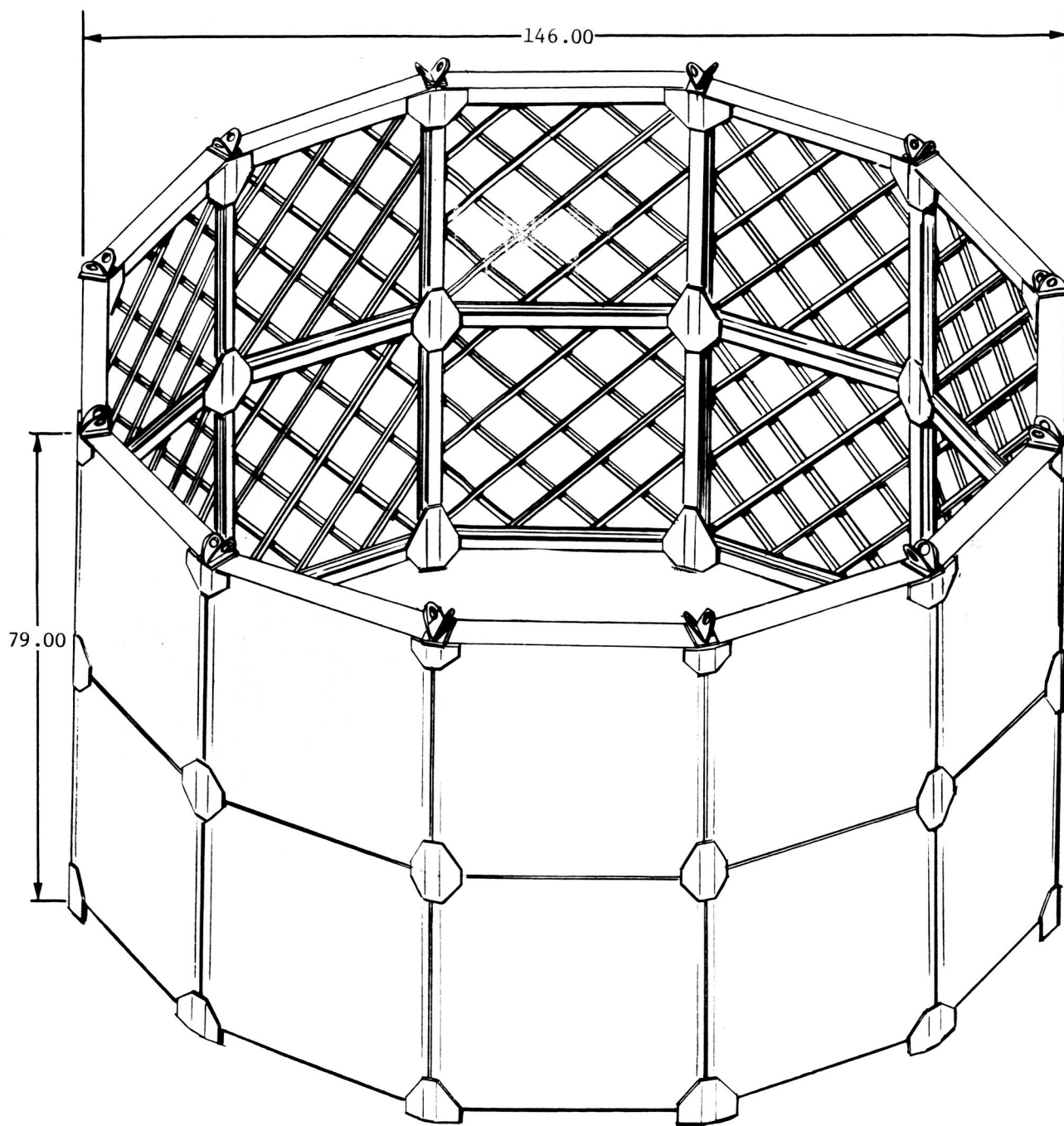


Figure 1

Graphite/Epoxy Orthogrid Shell Structure

Shell Fabrication

Fabrication effort during the first two quarters of Phase III has been directed towards the graphite/epoxy orthogrid panels. The basic elements of the final panel design, shown in drawing NAS8-318455, are the orthogrid skin laminated consisting of four layers of $\pm 45^\circ$ oriented unidirectional T300 graphite/934 epoxy tape, the foam/fiberglass stiffener web grid and stiffener flanges with eight layers of 0° T300 graphite/934 epoxy.

The main feature of the orthogrid panel design is that it provides the potential for low cost structural panels when advanced to the production phase where initial tooling costs can be amortized over a large quantity of panels. In addition, this low cost panel concept does not sacrifice structural efficiency and associated weight savings potential. The low cost potential is associated with the simplicity and adaptability to mass production of the precured panel details and of the panel assembly. The most innovative part of the fabrication method is the foam/fiberglass stiffener web grid billet fabrication and machining to size. The fabrication of these details in large billet form results in a low number of fabrication manhours per detail. The method of machining the required grooves in the individual web grid segments is readily adaptable to a mass production numerically controlled machining setup. The other details, skins and flange stiffeners, are very simple flat laminates and also adaptable to low cost mass production.

A total of twelve (12) of the required twenty four (24) graphite/epoxy orthogrid panels have been fabricated to date. All of the precured details for the other twelve (12) panels have also been fabricated.

- Panel Skin Laminates - The tool used to fabricate two full size skin laminates is shown in figure 2. The skin tool consists of a 6061-T6 aluminum plate milled flat on the top surface with 15° tapers milled along the two outside edges. The sharp edges at the 15° break line were lightly filed to provide a smooth radius. Three vacuum ports are included, two for pulling a vacuum on the bagged part and one for vacuum gage readout. The tool is scribed around the edges to aid in location of graphite/epoxy layers and fiberglass edge reinforcement for two different sizes of skin laminates required. The top surface was coated with DC-20 release agent and heated at 400°F for two hours. Before each tool usage, the top surface is also coated with a thin layer of cera wax to assure part release after cure.

A total of twelve (12) -005 and twelve (12) -003 skin laminates of the configuration specified on the panel drawing have been fabricated. The skin laminates all exhibit a small amount of warpage as shown in figure 2. This is caused by the difference in thermal coefficient of expansion of the graphite/epoxy layers and the fiberglass cloth edge reinforcement, however, this will not affect finished panel flatness since only a very small amount of pressure is required to flatten the laminates. The cured skin laminates are averaging 0.071 cm (0.028 inches) thick in the center region and 0.094 cm (0.037 inches) thick in the edge reinforced areas and weight 1120 grams (2.70 lbs) each.

- Panel Stiffener Flanges - The orthogrid panel stiffener flanges are cut from a laminate consisting of eight layers of 0° oriented graphite/epoxy and three layers of style 112 fiberglass cloth. The basic laminate is 183 cm (72 inches) long by 89 cm (35 inches) wide and is cured on a flat aluminum tool prepared in a manner similar to the skin laminate tool. All eight (8) of the required flange laminates have been cured with finished thickness averaging 0.122 cm (0.048) inches and weighing 3350 grams (7.38 lbs) each. Stiffener flanges for four complete orthogrid panels can be cut from one of the basic laminates.

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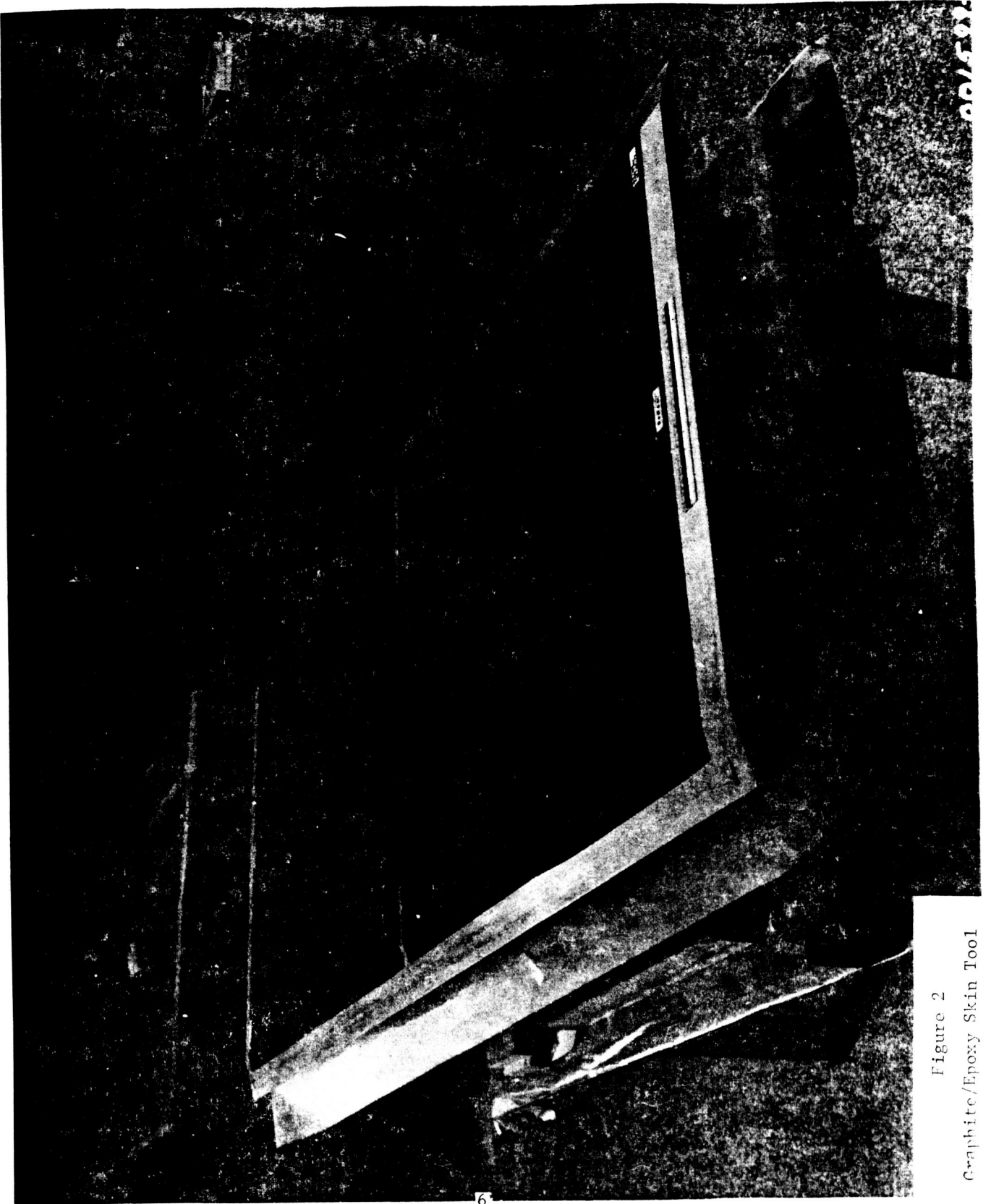


Figure 2
Graphite/Epoxy Skin Tool

Panel Stiffener Web Grid

The completely assembled panel web grid billet tool is shown in figure 3. The triangular and square components were fabricated by welding half inch thick 6061-T6 aluminum plates together and milling the surfaces to the final dimensions desired. The sharp corners were filed to produce an eight inch radius. The complete tool was assembled using wooden spacers to simulate the fiberglass/foam details to be used during billet fabrication.

The foam used in the web-grid billets is a 56.1-kg/m^3 (3.5-lb/ft^3) polyester designated ST 823. A main consideration in selecting this particular foam is that it retains its stiffness to temperatures of 422 K (300°F), which is important for further bonding using FM-24 film adhesive cured at 394 K (250°F). The material was purchased in sheet form ready for slicing to size for the billet assembly. Foam detail slicing and grinding is shown in figures 4 and 5. The FM-24 film adhesive (0.098 kg/m^2 (0.02 lb/ft^2)) is applied to all surfaces of the foam segments before assembly of the billet. Square and triangular fiberglass segments to be included in the grid billet are precured on aluminum tools and cut to size for inclusion in the billet assembly. The fiberglass laminate consists of fiberglass cloth/5208 epoxy resin. A typical fiberglass detail is shown in figure 6. The flat fiberglass sheets required for the outer edges of the billet are precured and cut to size. The foam and fiberglass details with thin FM-24 film adhesive on all surfaces are assembled into the holding tool (figure 7) and the billet assembly is cured at 394 K (250°F) for one hour. A cured billet with aluminum tooling removed is shown in figure 8. The cured billet must be cut in half so that it will fit in a band saw. The billet segment is sliced to rough size on a band saw as shown in figures 9 and 10. The web grid is ground to a specified thickness using the grinding fixture shown in figure 11. The diagonal stiffeners and the edge stiffeners are ground to three different depths to allow for straight-through transfer of stiffener flanges at intersections. This is done using the fixture shown in figure 12. Four slice segments are required to form a single web grid assembly. The segment bonding fixture is shown in figure 13. The FM-24 film adhesive is applied to the down (skin) side of the web grid. The web grid (figure 14) can now be sealed in a plastic bag and stored in a freezer until needed for final panel assembly.

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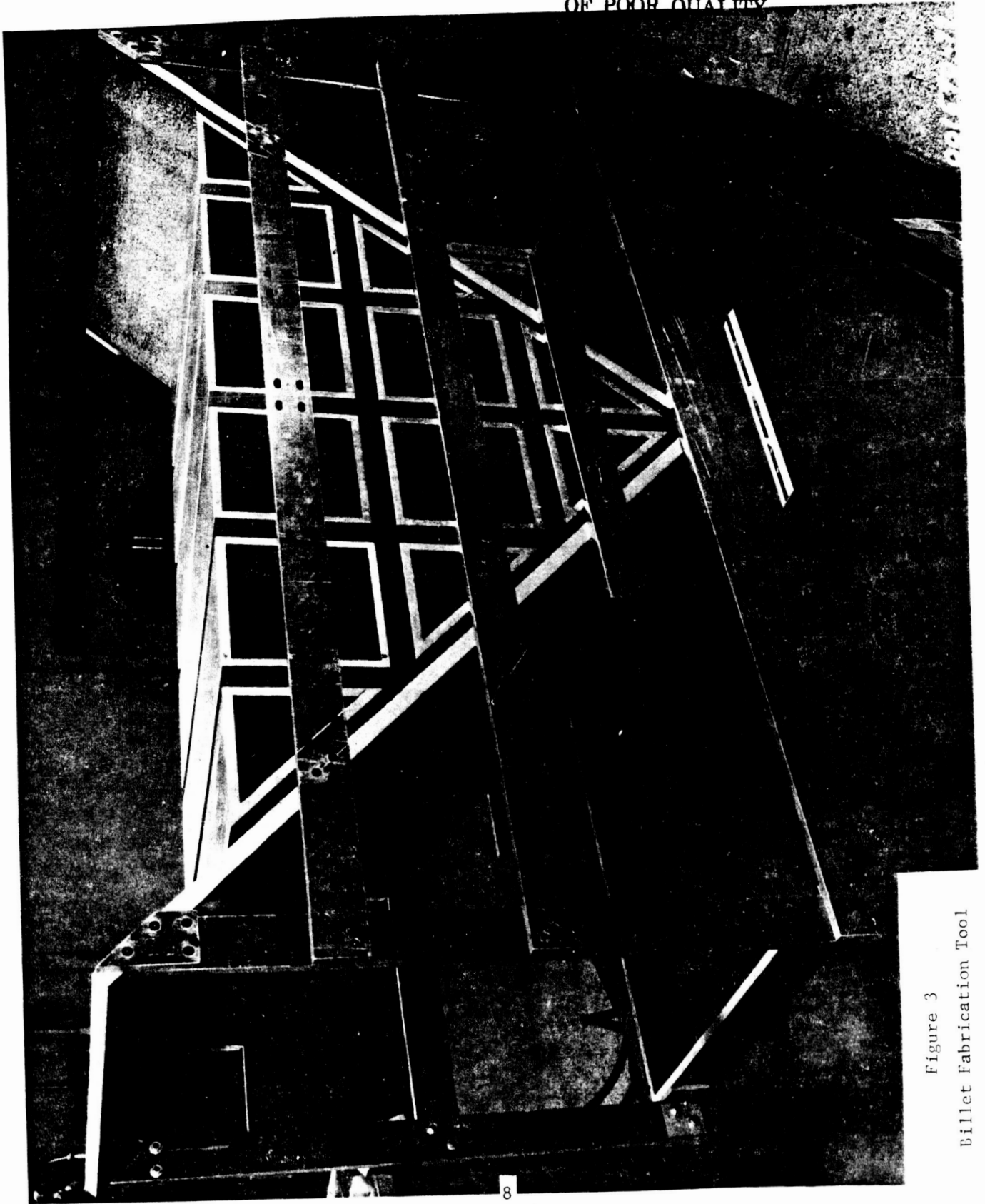


Figure 3
Billet Fabrication Tool



Figure 4

Billet Foam Cutting

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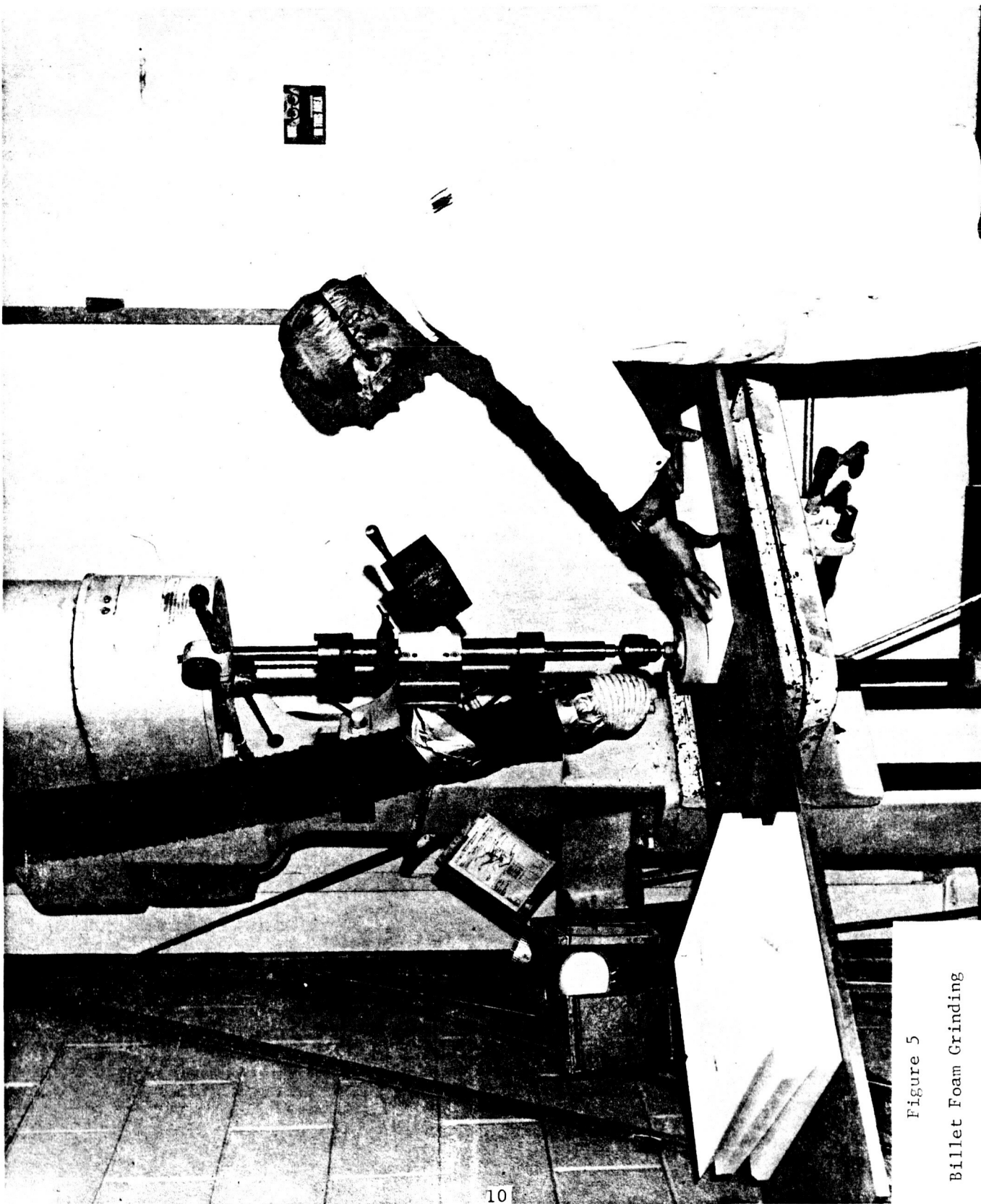
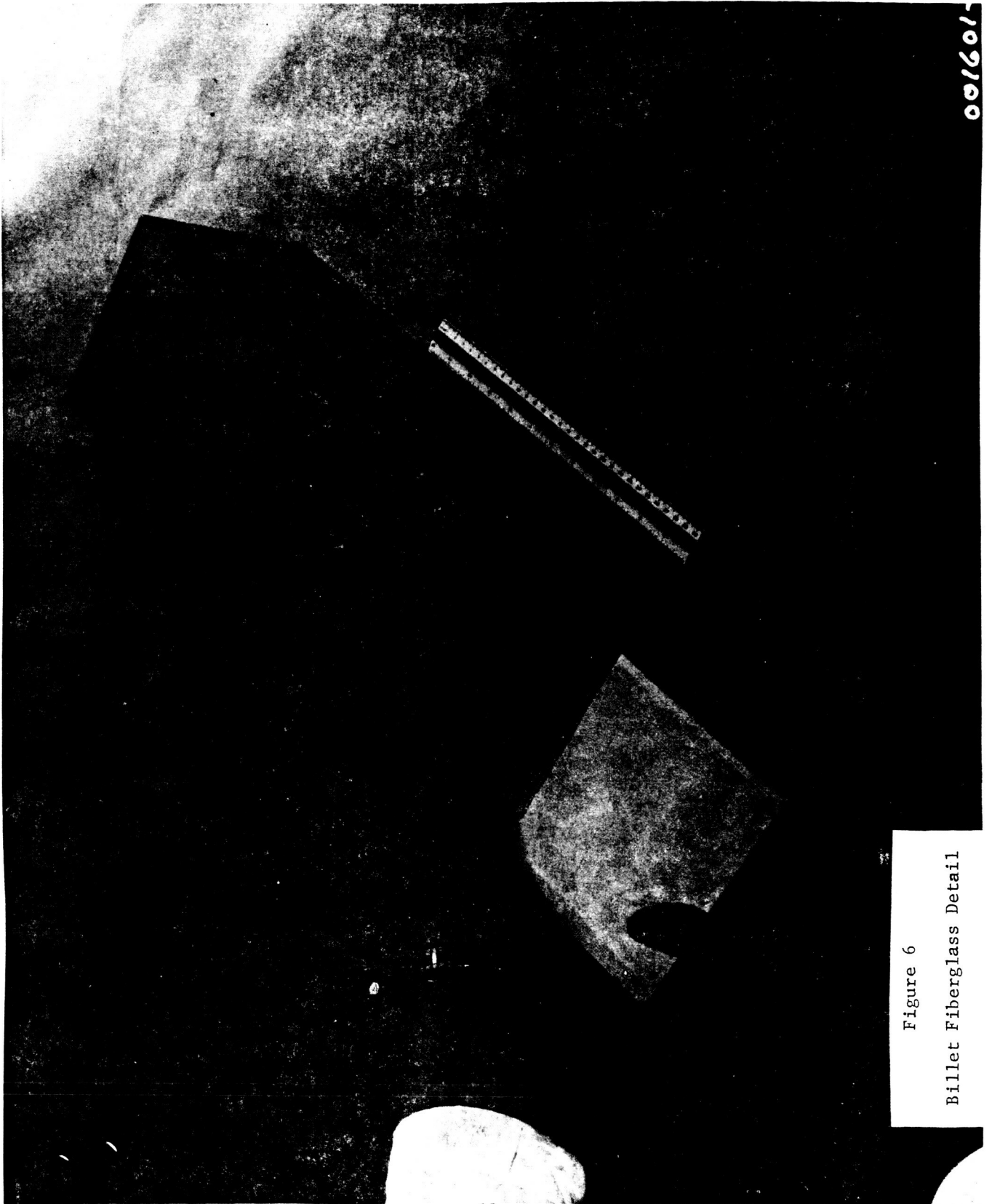


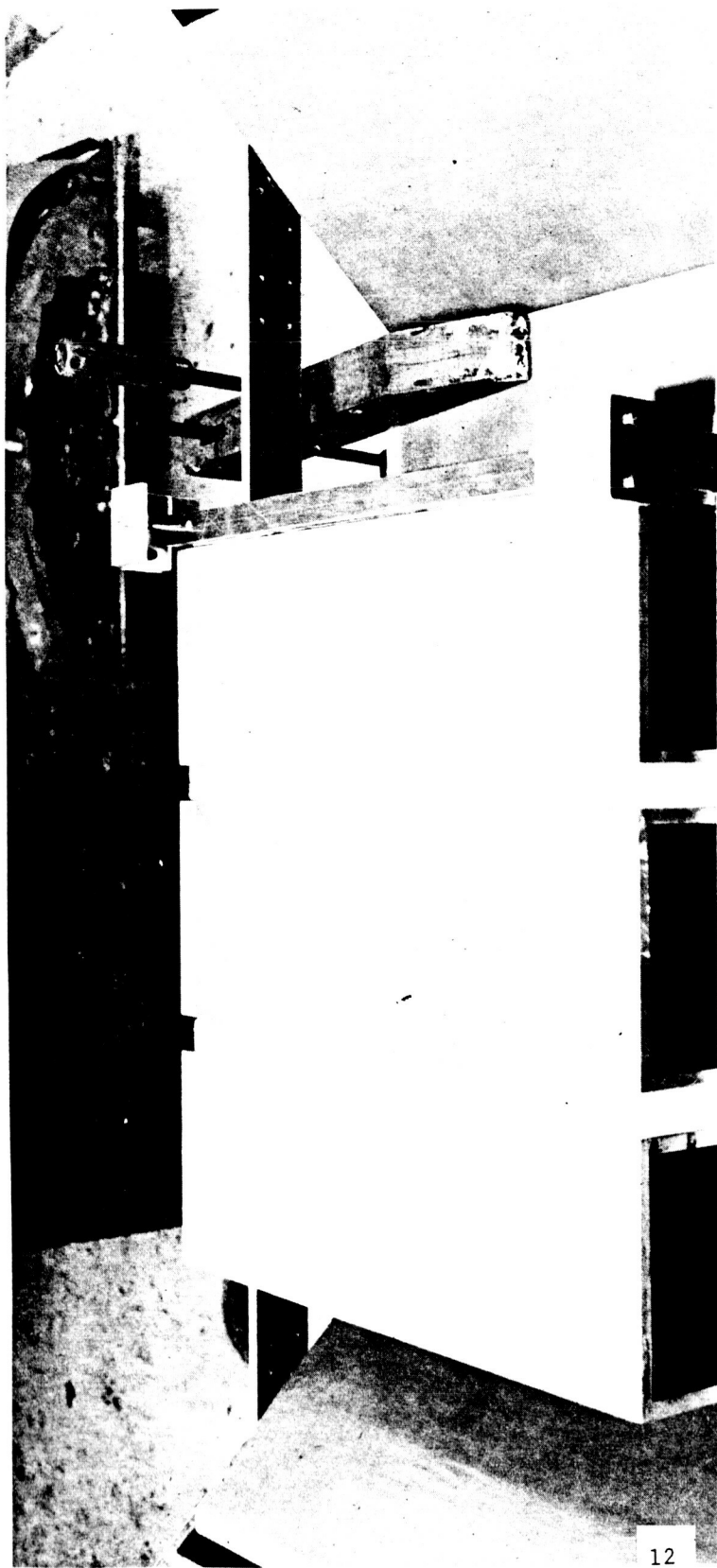
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Billet Foam Grinding

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Figure 6
Billet Fiberglass Detail



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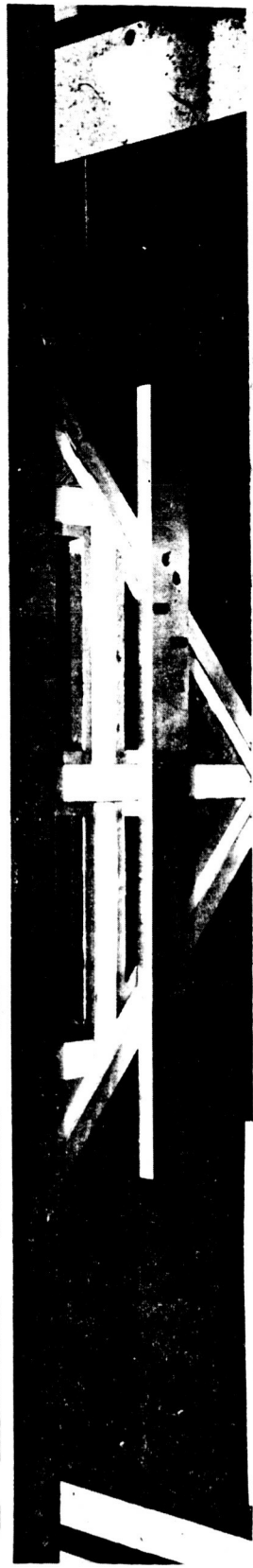
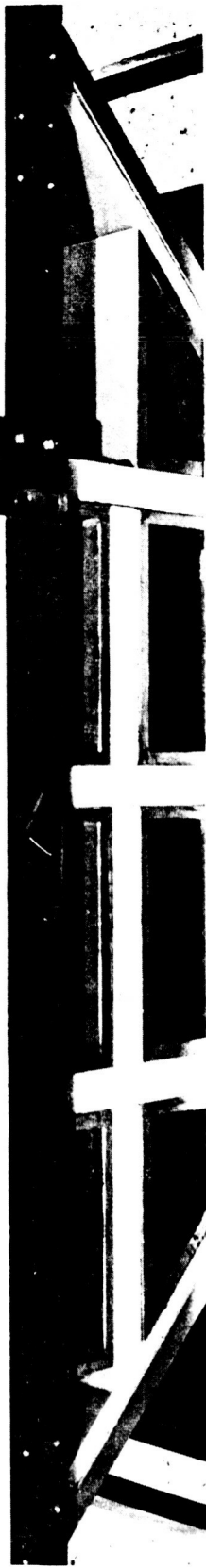


Figure 7

Billet Assembly

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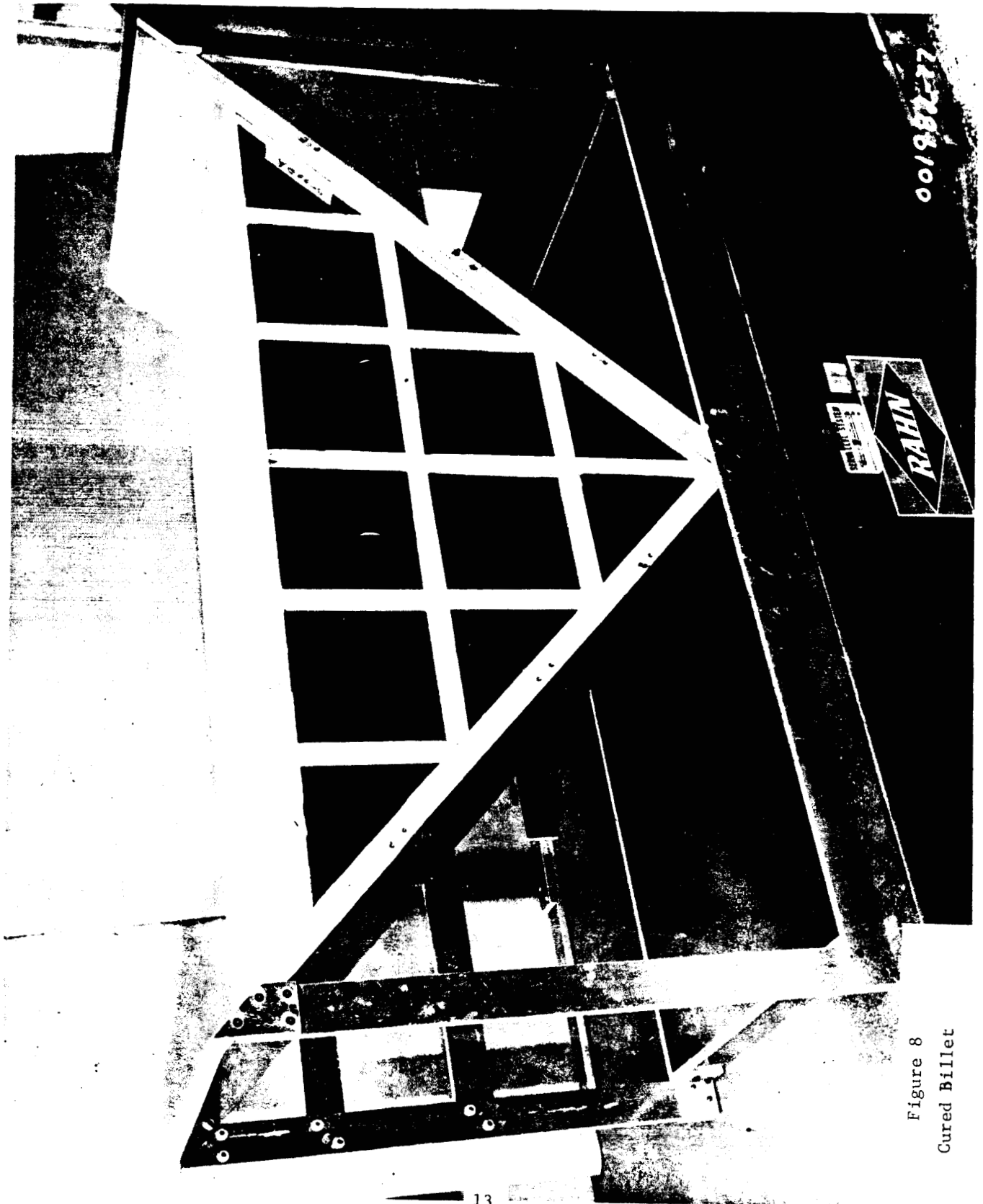


Figure 8
Cured Billet

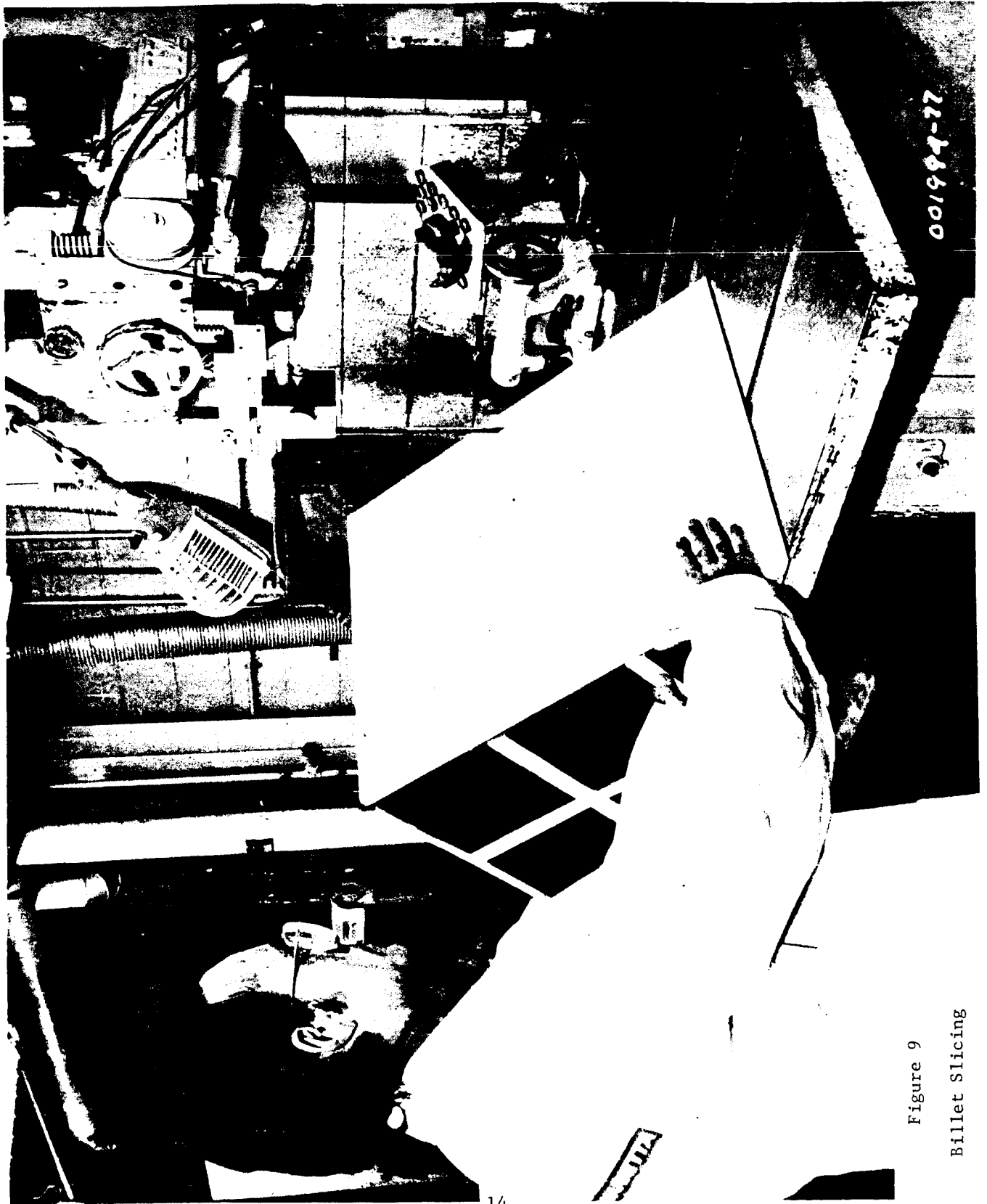


Figure 9
Billet Slicing

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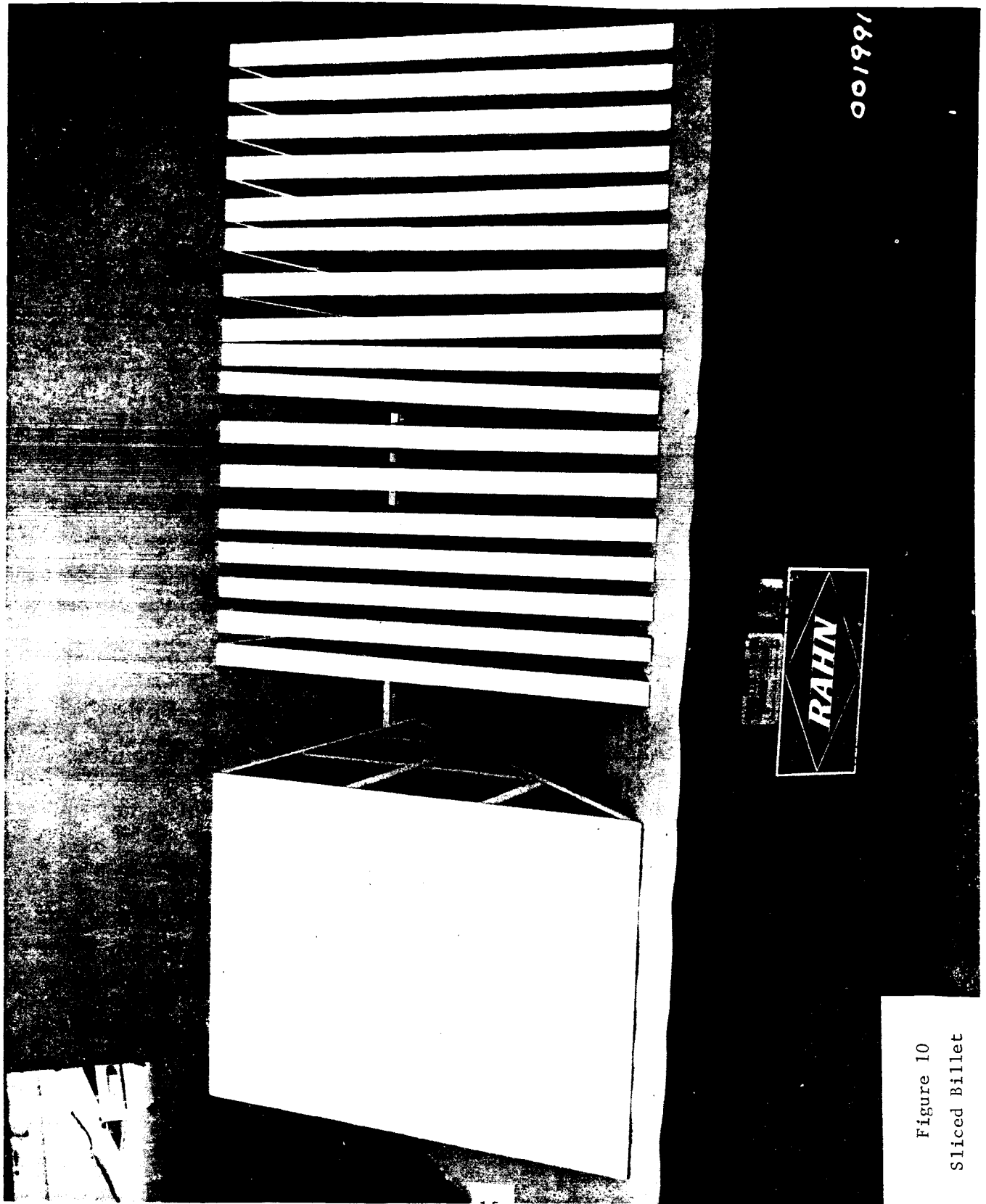


Figure 10
Sliced Billet

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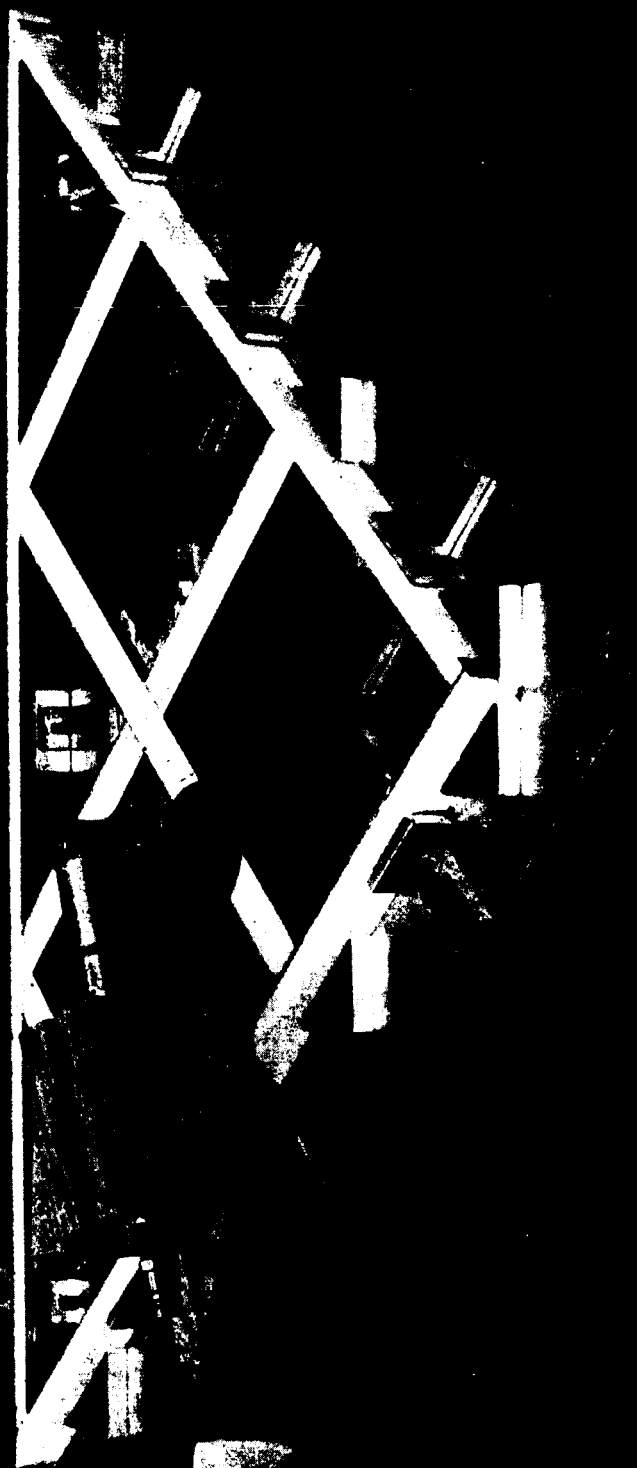


Figure 11
Web Grid Grinding

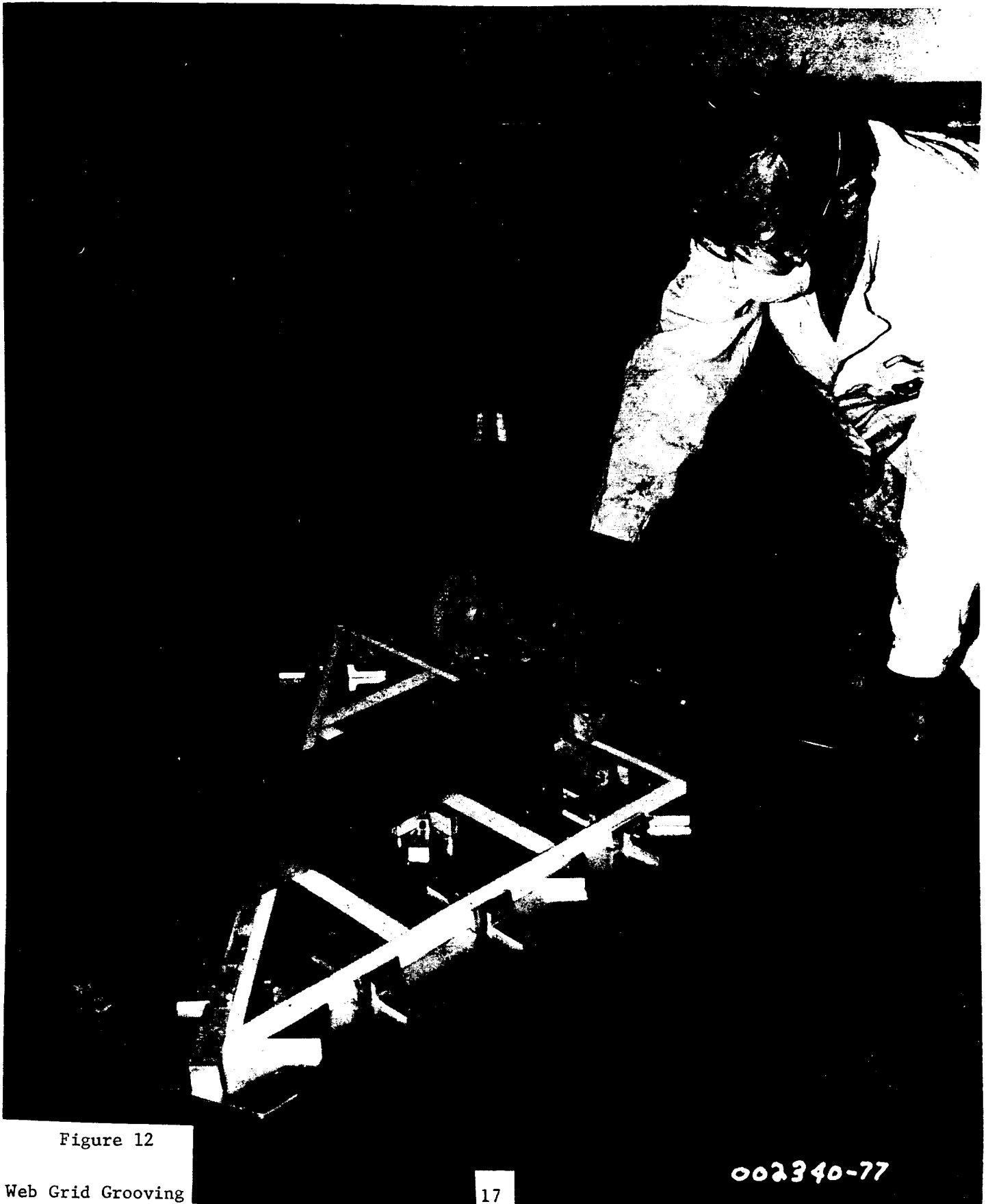
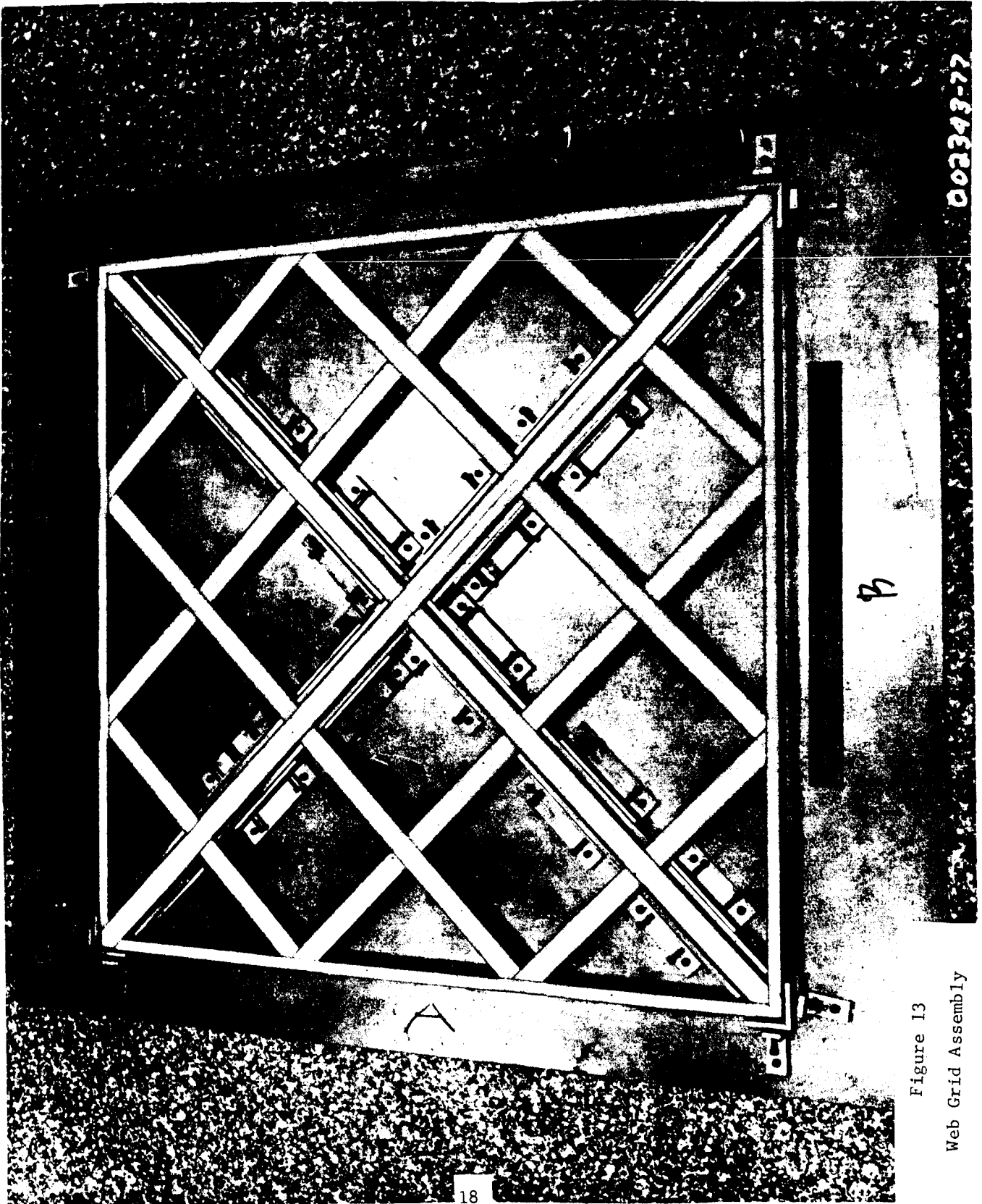


Figure 12

Web Grid Grooving



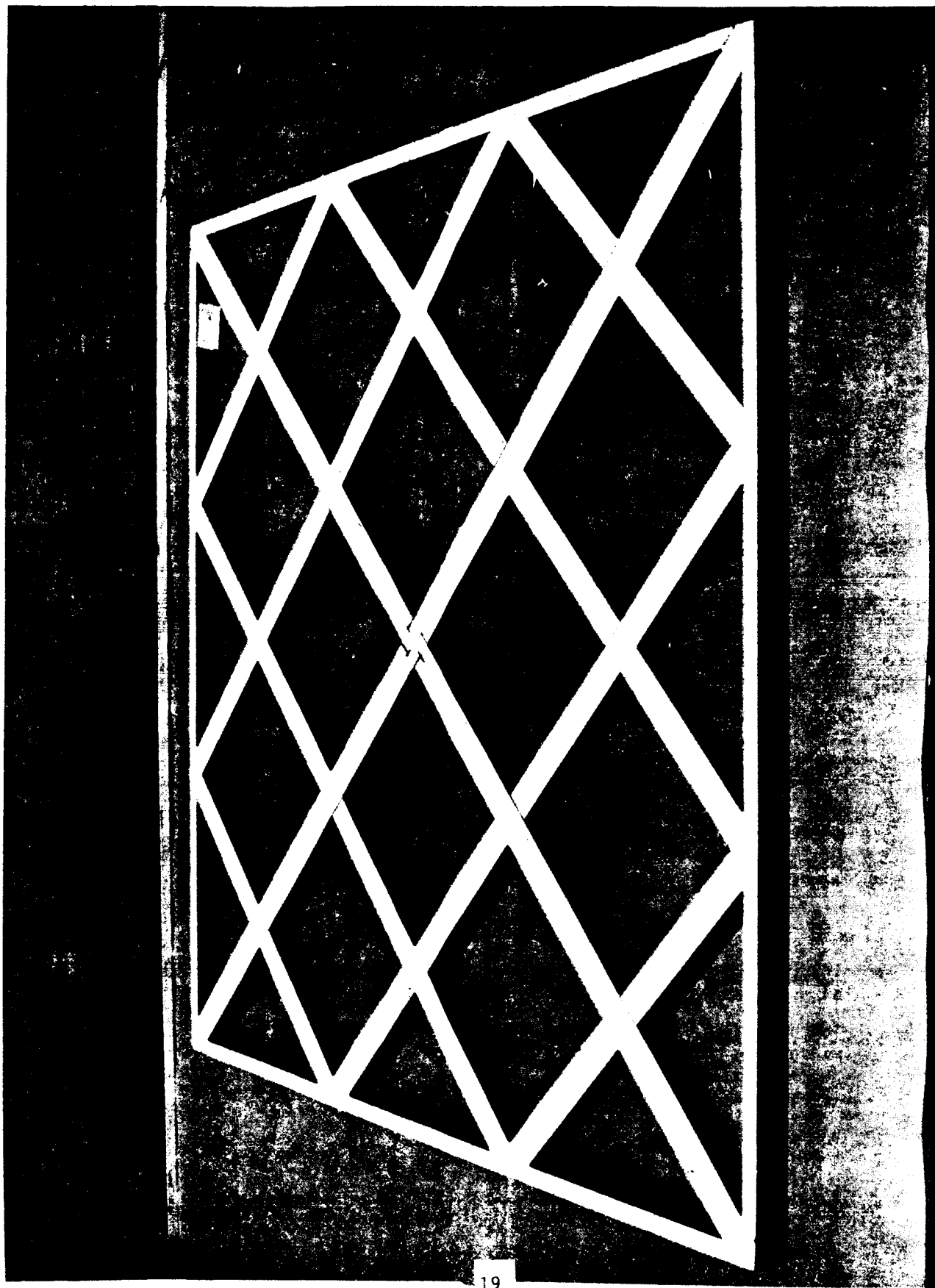


Figure 14
Completed Web Grid

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Panel Assembly

Two orthogrid panels are assembled and cured on the tool shown in figure 15. The skins are first sanded and cleaned with MEK in the grid bond regions as shown in figure 16. The fiberglass/foam web grids with FM-24 adhesive applied to the bottom sides are then placed on the skin laminate. The stiffener flanges are next cleaned, FM-24 adhesive applied to the bottom side and positioned on top of the web grids. The details are all taped in place to prevent slippage during cure. Wooden filler blocks and aluminum shims are placed in the grid to partially support the vacuum bag to allow for uniform normal downward pressure during cure. A vacuum bag is applied to the top surface of both panels and the assembly cured at 394°K (250 °F) for 2 hours. A finished panel is shown in figure 17. Ten of the completed panels are shown in figure 18.

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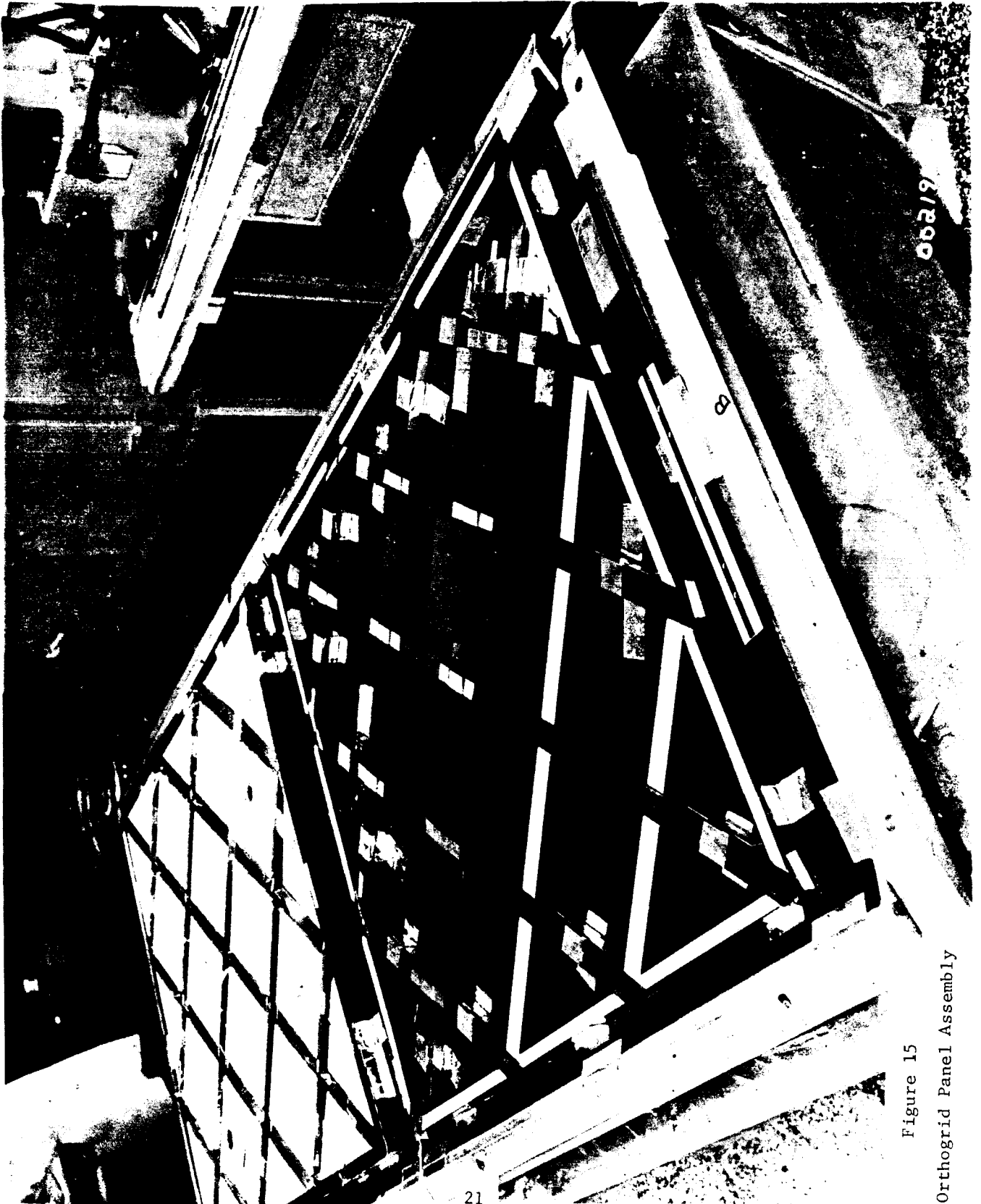


Figure 15
Orthogrid Panel Assembly



Figure 16
Faceskin Cleaning

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Figure 17
Completed Graphite/Epoxy
Orthogrid Panel



Figure 18
Graphite/Epoxy
Orthogrid Panels

Schedule and Budget

The master program schedule shown in figure 19 outlines the major program milestones for the reduced scope program. The budget available is currently the subject of negotiation and will be fully defined in the next monthly financial report.

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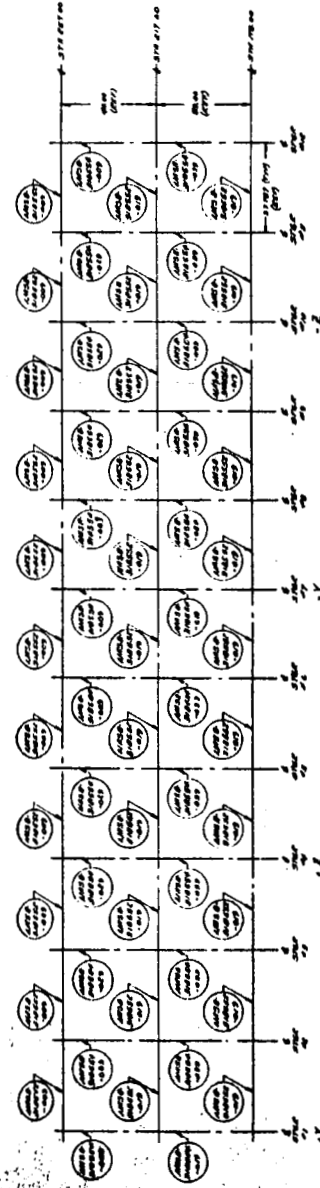
Figure 19

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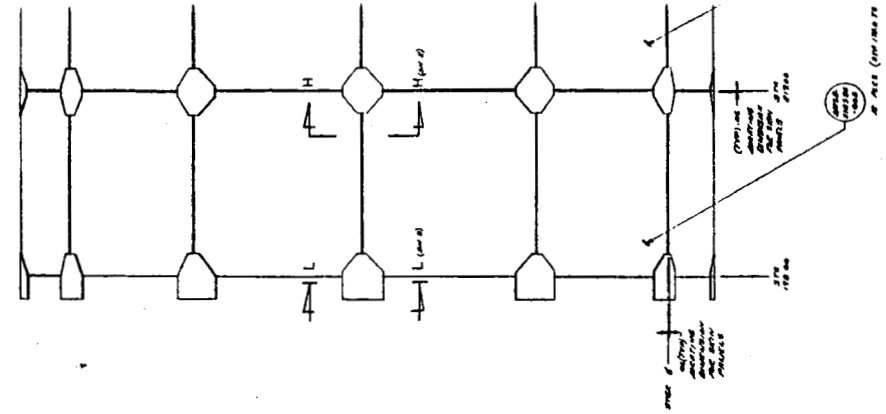
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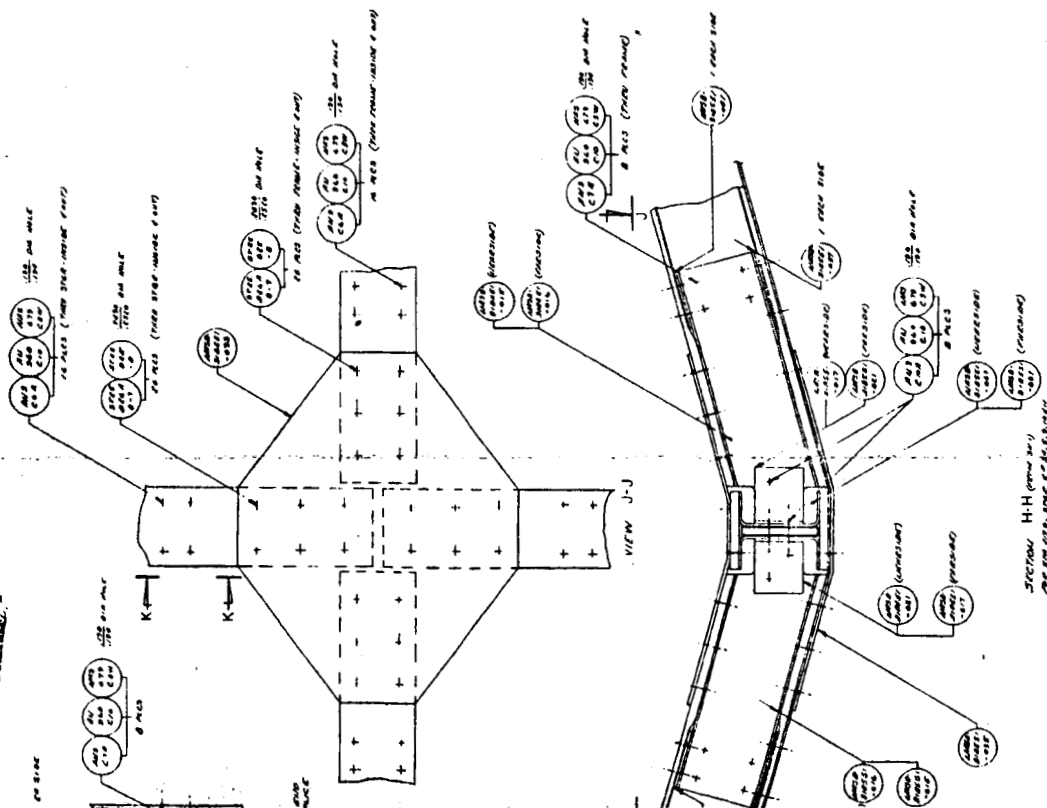


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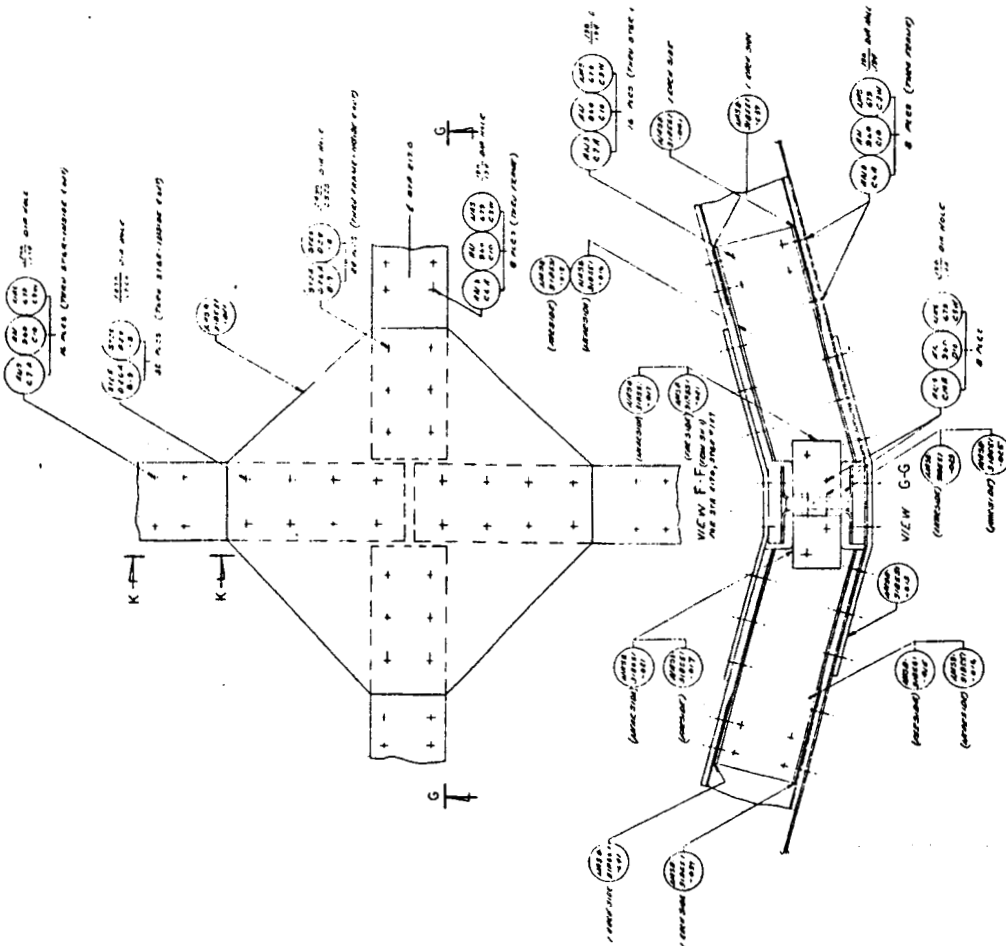
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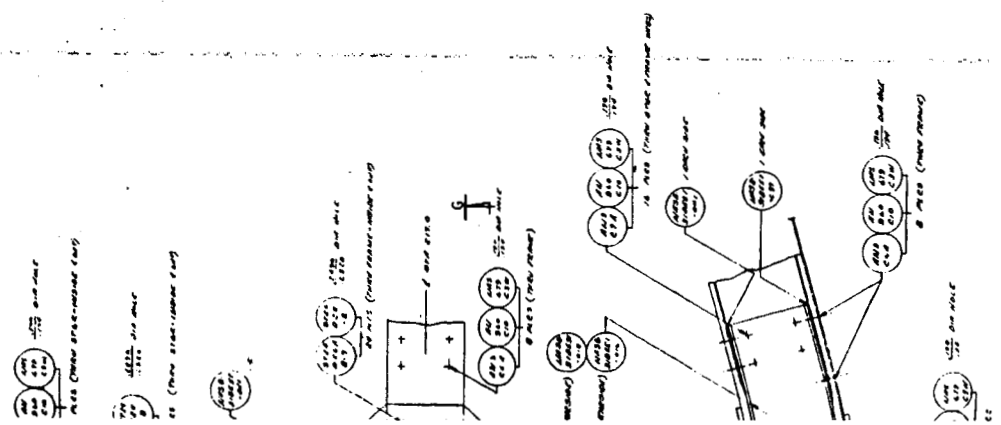
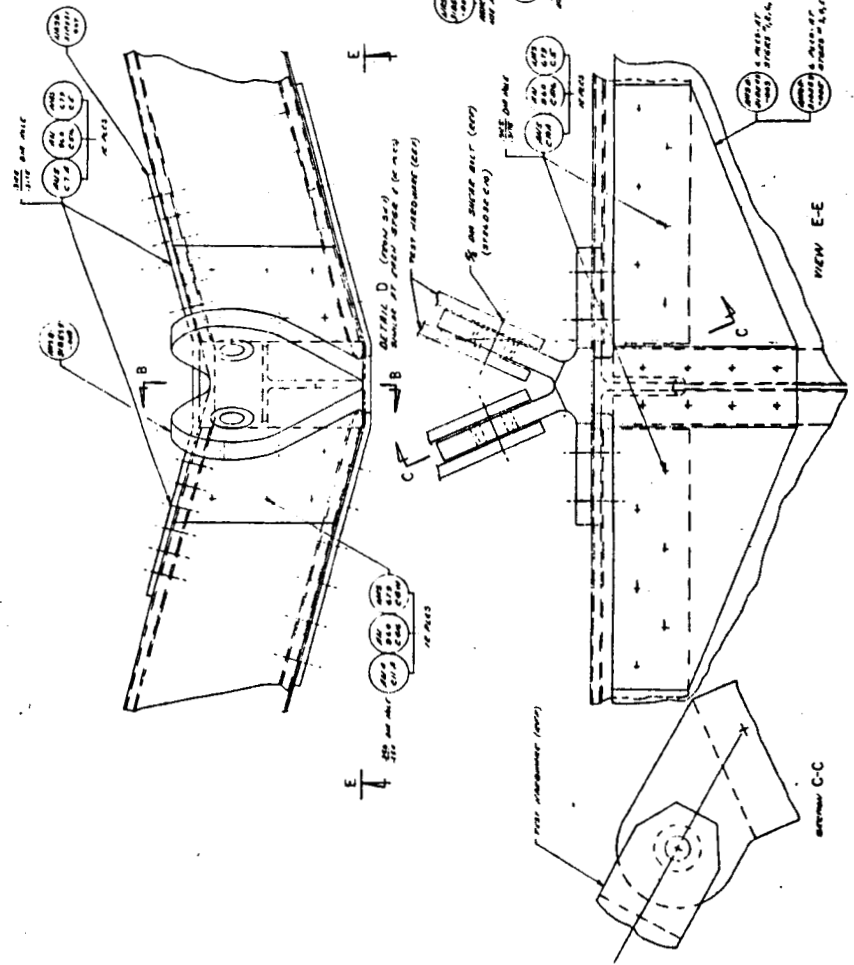


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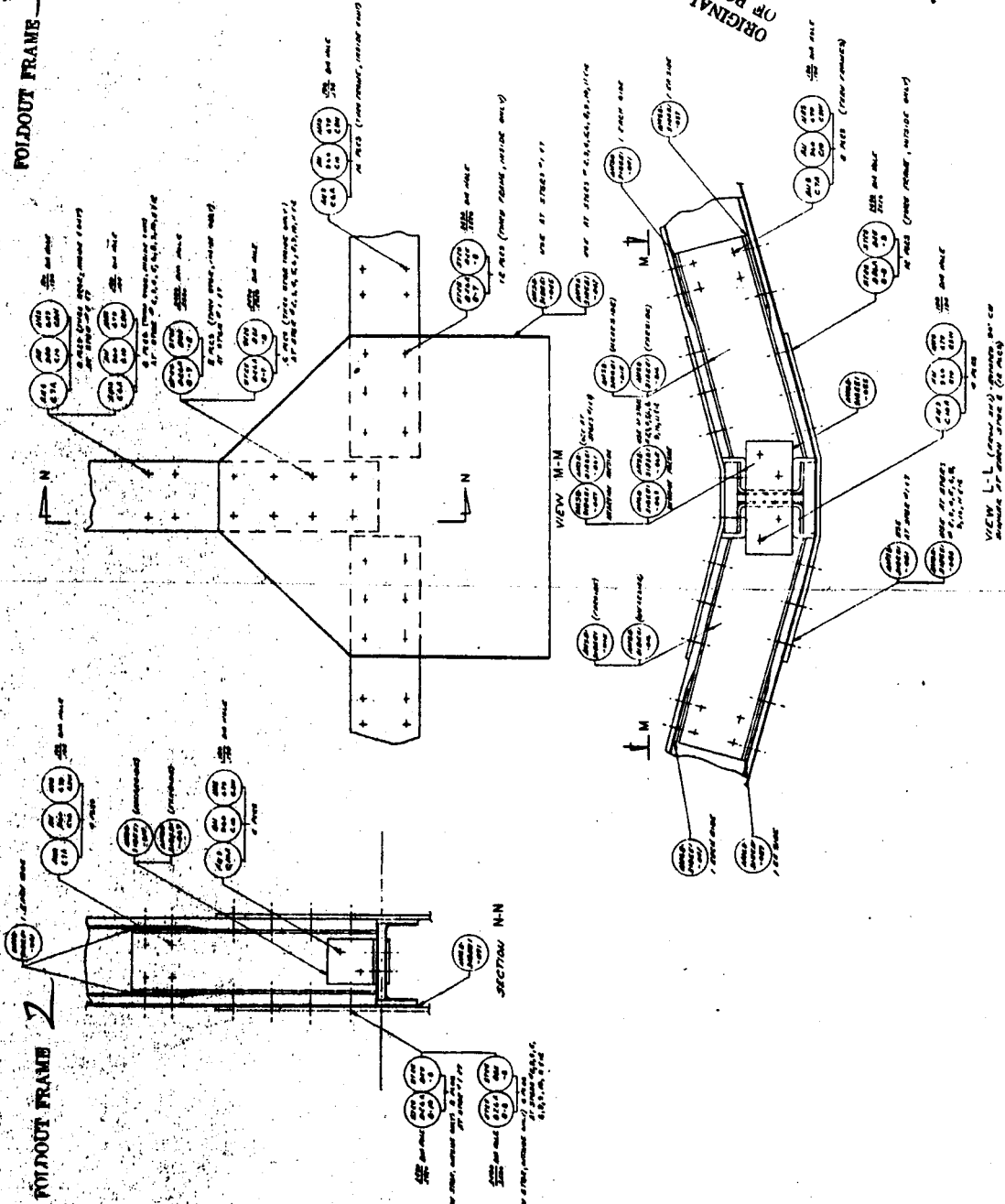
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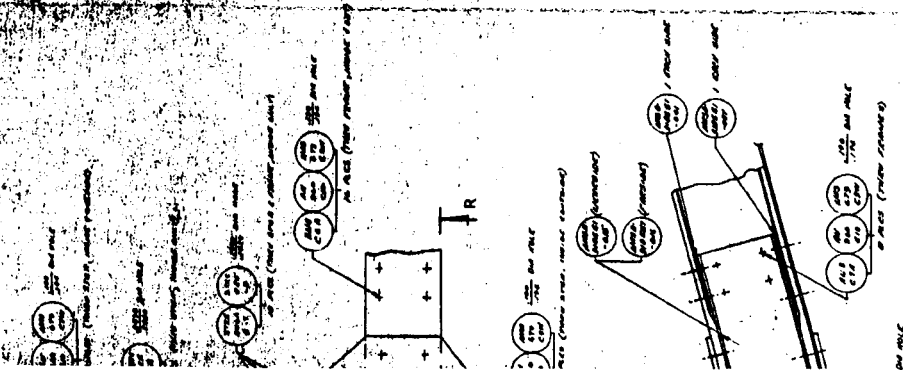
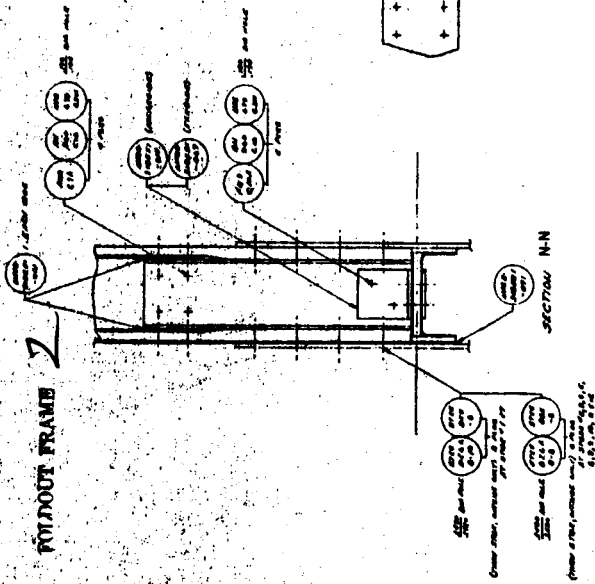




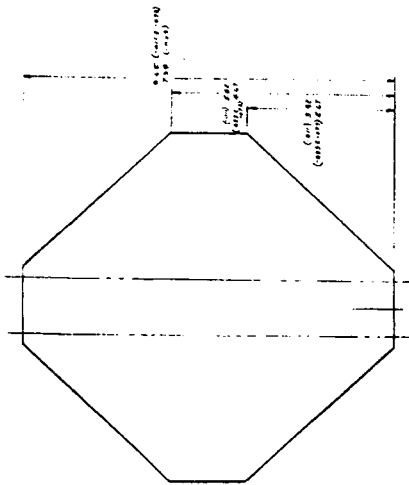
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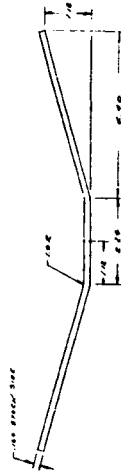
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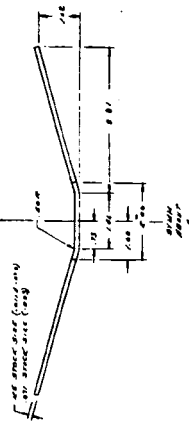
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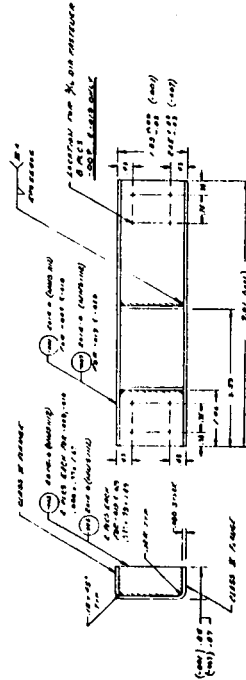


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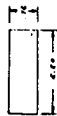


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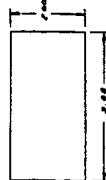
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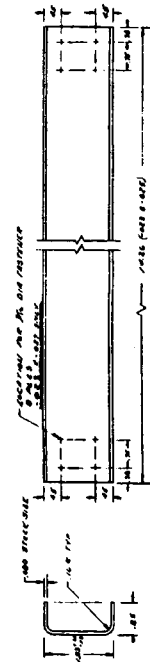


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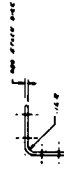
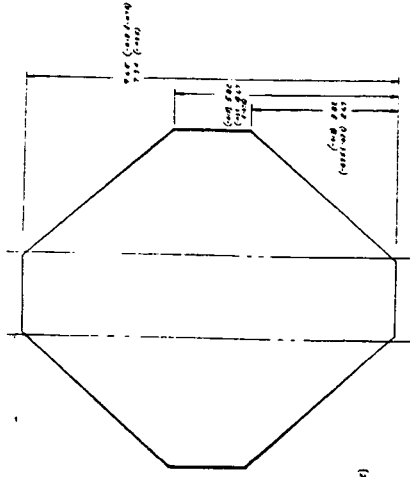
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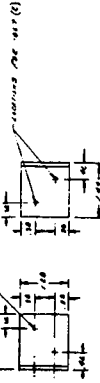


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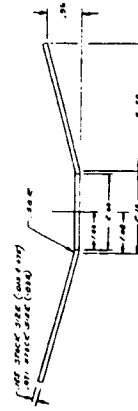
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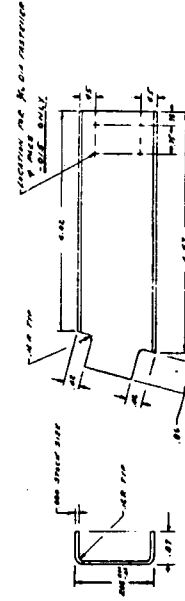
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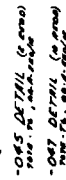
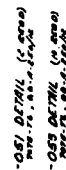
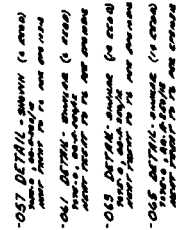
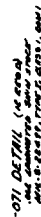


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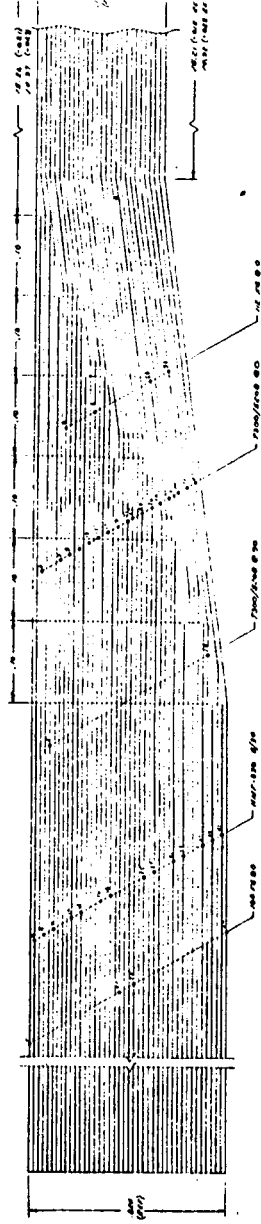


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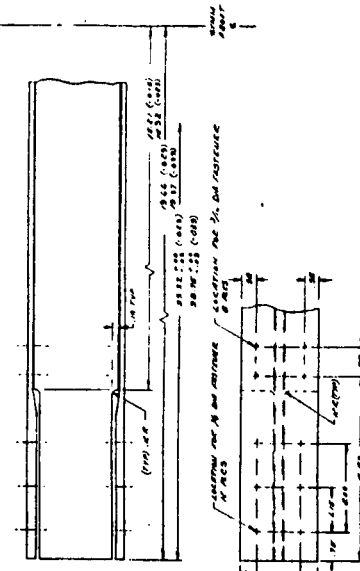
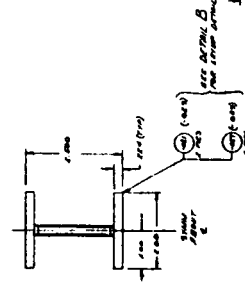
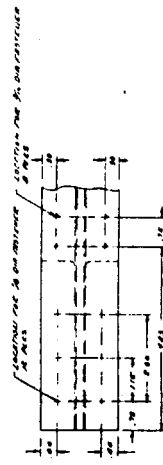
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DETAIL B - SECTIONAL VIEW - SEE 1 - DET. B FOR DIMENSIONS AND ASSEMBLY DETAILS
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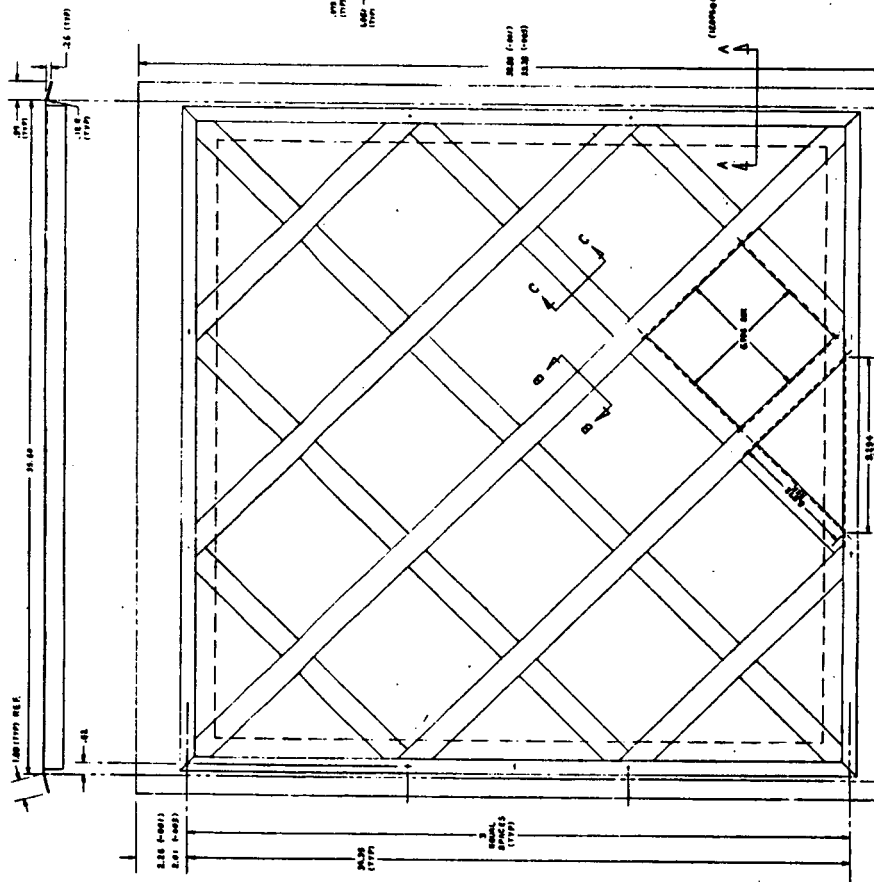
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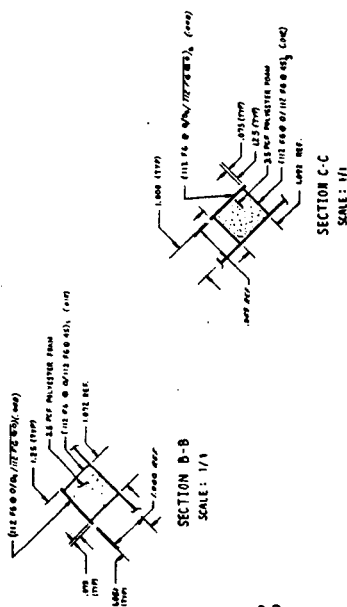


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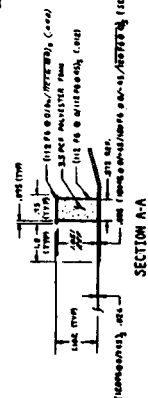
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-001 DETAIL (12 pages)
-003 DETAIL (10 pages)



SECTION C-C
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SECTION A-A
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